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# 2.4 Sustainable factory profile: a concept to support the design of future sustainable industries

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**Abstract**

The German industry caused more than a quarter (27.8%) of the total energy consumption. Factories have a high influence in resource saving during the realization of a factory and the production process. First "CO2 neutral factories" and "zero-emission factories" were realized in the last years. But they are just point solutions and these concepts are rarely used by enterprises in Germany. As part of an energy efficient optimization of factories, it is necessary to extend the focus of planning and to consider the location, the design, the integration into the environment and the potential of modern energy efficiency. Particularly the factories provides additional high saving potentials for the company. Low emission production methods or resource-efficient building practices offer opportunities for integrated environmental factory design. These approaches are integrated into the comprehensive concept "Sustainable
Factory Profile (SFP)" which is described in this paper.

**Keywords**:
Factory planning; Green Factory; Sustainability; Sustainable production

## 1 INTRODUCTION

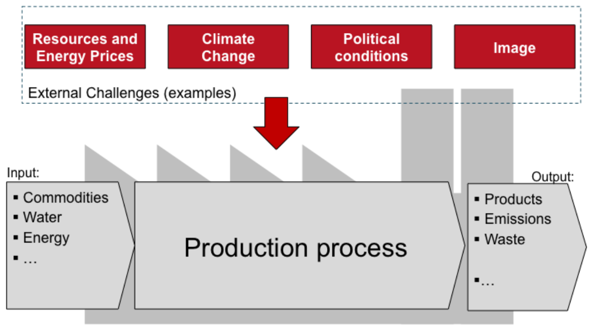


Figure 1: External challenges for the factory with focus on sustainability [3]

The factory as a place of value adding activities is forced to adapt to the requirements of the turbulent market. The customer's demand for short delivery times, innovative and sustainable products in connection with decreasing prices leads to new challenges. [1] To analyze which external challenges influence the factory, The detailed analysis of the interaction between the factory and its environment is necessary. Basically, two fields of planning can be identified for the sustainable factory planning: on the one hand the input and output and on the other hand the production processes within the factory as well as the building structure. [3]

The input is characterized, for example, by goods, water or different forms of energy; whereas products, waste and emissions define the output.

The production or manufacturing equipment, the material flow, the technical building system as well as the employees characterize the second field of planning, the building structure and the production process. With link to the organizational process, the factory is a broad field of action for sustainable optimization and design. Next to the classic challenges of the turbulent market new requirements have to be recognized during the factory planning process. The institute for advanced industrial management defines the following four external challenges as new requirements in the factory planning process: [3]

*Resources and Energy prices*: Energetic optimization is necessary to reduce costs.

*Climate changes:* The CO2 caused issues must be reduced to make a contribution to the reduction of the global warming.

*Political conditions*: A plurality of laws and norms with the focus on energy saving and sustainability have to be considered during the whole planning process.

*Image*: Energy efficiency has become an important factor of the enterprise image.

Beside these external influences also internal influences have to be taken into account. Rising costs for energy do not only have their origins in rising prices, but also in the increasing demand of energy due to automation of the production. This is caused by the application of modern energy-intensive production processes, for example by laser welding. [3]

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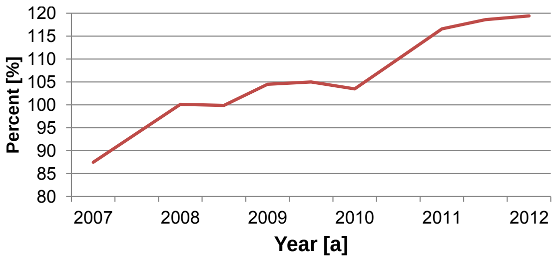


Figure 2: Development of electricity prices of industrial consumers [5]

Traditional rationalization fields like lead times, long transportation ways or inventories are considered as exhausted. The sustainable optimization as a field of activity still has a high potential for improvements. [3] More and more standards like the ISO 14001 recognize the sustainability as a field of optimization and standardization for companies. But a holistic approach on this focus is still not realized. [4]

## 2 EXTERNAL CHALLENGES FOR SUSTAINABLE FACTORIES

### 2.1 Resources and energy prices

The increase of the energy prices during the past years is one of the main arguments for many enterprises to deal with the subject of efficient energy usage. The use of electricity is becoming a relevant economic factor caused by the increasing expenses. Figure 2 illustrates the younger development of electricity prices for industrial usage in Germany. The pricing for industrial consumers in Germany increased by 20% in the last four years. A similar development has to be considered for other forms of energy. One example is the development of the oil import price. The price increased by 35% to the reference year 2008 in Germany. [5]

Compared to the German development of energy prices the situation in other European countries is more serious. For example the price for electricity in Spain has risen by 120 % in the last ten years. Furthermore, a significant rise in prices is predicted for the future. [5] Even more dramatically is the development of gas prices during the last 12 years. Compared to the year 2000 a rise in prices of 142% can be detected. [6] For this reason, the efficient use of energy during the production process becomes a competitive factor for enterprises. Decreased energy costs with constant profit allow to declining sale prices of single products by which a competitive advantage can be realized. [7]

### 2.2 Climate change

The climate protection by reducing the greenhouse gases defines the second external challenge, which has direct influence on the factory operation and planning. This so called greenhouse effect is in principle of natural kind and has warmed the earth's surface from below 18 degrees centigrade on an average of 15 degrees centigrade today. [8] Nevertheless, by the increase of the industrial production the development of greenhouse gases raises stronger than the forecasts predicted. As a result, the so called European Union Emission Trading System, came into effect in 2005. [9] This system includes the regulation of

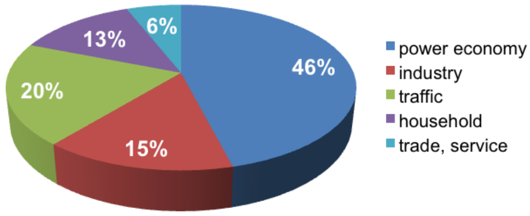


Figure 3: Distribution of $CO_2$ emissions in the year 2011[5]

greenhouse gases and restricts the allocation of $CO_2$-emission rights, or the commitment of a price for $CO_2$-emissions. Enterprises need to hold certificates, which are bought and charged off depending on the occurred emissions. Actually, every emitted ton $CO_2$ implies a payment of 100 euros.

In the sequel the industrial CO2 emissions in Germany could be continuously lowered during the last years. Nevertheless, it is of high relevance that this trend in Germany will be continued by technological and organizational changes. This statement is supported by the distribution of $CO_2$ emissions in the year 2011 shown in figure 3. The industry has a share of 15% of all $CO_2$ emissions in Germany. Next to the power economy (46%) and the traffic (20%) it is the third largest sector concerning greenhouse gases. [10]

### 2.3 Political conditions

A responsible use of natural resources and the protection of the environment are accepted as important development conditions worldwide. In 1992 the conference of the United Nations about environment and development (UNCED) confessed. Under the direction of Gro Harlem Brundtland the sustainability as a normative leading of "international politics". was exclaimed. Sustainability means „the present generation satisfies its needs without endangering the ability of the future generation being able to satisfy its own needs“. [11] This statement still influences the German and European (EU) legislative. In the following, only an extract of laws and norms will be introduced.

In the *Federal Immission Control Act* (BImSchG) the „protection is regulated before injurious environmental influences by air pollutions, noises, vibrations and similar processes“. Within the scope of this law other orders, administrative regulations and technical instructions are included, as, for example, the orders for an issue limitation by light-brief halogen hydrocarbons, for requiring permission arrangements or a case order directive of the EU. Requiring permission arrangements are for example, heating power works or chemical plants. [12]

*Certification Systems* shows no law, but a voluntary measure for the benchmark and evaluation of the factory. In this context, the evaluation should not only include ecological aspects, but should be aimed on a comprehensive consideration of the whole life cycle and all sustainable aspects like human or economic factors. A big part of this certifications system is the lifecycle assasment (LCA). The LCA is a tool to calculate the impact of a product on the environment [13] [14]

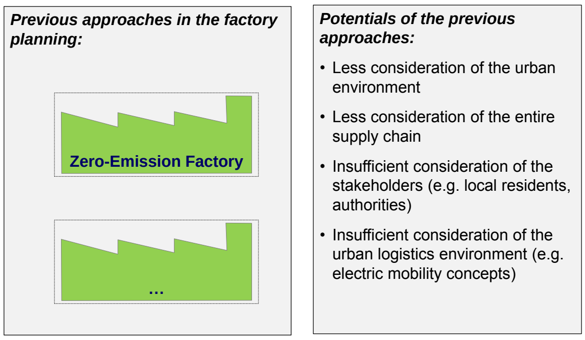


Figure 4: Previous approaches in factory planning [18]

The *Energy Saving Ordinance (EnEV)* is an important step of the energy policy and climate protection politics of the Federal Government of Germany. On this occasion, the architectural heat insulation of the building structure as well as the energy efficiency of the used technical building system (heating, airing, cooling, lighting) is considered. [15]

The environmental information law (UIG) defines, that each company in Germany is entitled to enable the access to information about the environment, which is given to an authority, to see and also to spread. [16]

Those described external challenges for the sustainable factory planning leads to new industrial and research approaches. This is caused by the rising complexity which all of this external challenges cause by considering them during the planning and operation of a factory.

## 3 PREVIOUES APPROACHES AND PROBLEM STATEMENT

Due to the intensified attention of the efficient use of energy and resource within the factory, the so called „zero-emission factories" or also "environmental fair factories" were developed since the 1990`s. [17] The Solvis GmbH realized one example of such a "zero emission factory" in 2002. The Solvis GmbH is a medium sized manufacturer of solar energy technology. The factory is characterized by its large collector and photovoltaic surfaces, a rapeseed oil blocktype thermal power station and a very good thermal insulation. [18] This all leads to a factory with zero emissions. Another example of an environmental fair factory is the so called „Blue Factory" built by Volkswagen in Emden. This environmental fair plant is realized for example by a modern paint shop, which uses fewer chemicals than conventional ones, a heat house operated by long-distance heating and a company-owned purification equipment. Furthermore, Volkswagen uses biomass to produce environmental fair heat supply and builds solar and wind power plants for the electric supply. [19]

Meanwhile, the potentials of a sustainable factory are not only recognized for reasons of marketing. The realization of the potentials became an established target value of the enterprise. But the main problem of those research approaches and industrial realization is, that the system boundaries of those approaches end with the factory premises. Those approaches are in most cases „isolated solutions ". (Figure 4) In order to act however effectively in the sense of a sustainable production the system borders of the past approaches have to be extended to unlock the whole potential of sustainable factories. The factory cannot be

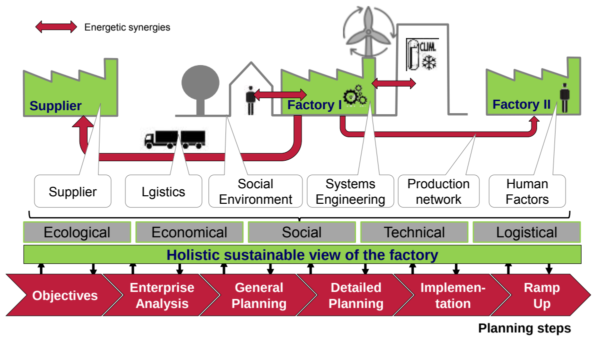


Figure 5: Holistic sustainable view of the factory [3],[20], [21]

planned and operated as an isolated system under systems, but rather has to be integrated in the whole environment. The sustainability of the factory does not end at the factory gate.

To realize a holistic view on the factory, it is necessary to recognize all relevant factors already in the planning process. Figure 5 reveals a draft of the holistic sustainable planning process of the factory. As described before, the system borders have to be extended. This includes the recognizing of the suppliers of the factory. A sustainable production process must recognize the whole value stream including all suppliers or other factories within the production network. Next to this, the influence of the social environment and human factors has to be considered during the planning, realization and operation of a sustainable factory. The basic structure of the factory planning process is not recognizing the actual situation. The classic factory planning process is structured in seven phases that are processed sequentially. [20] At the end of each phase a milestone is reached. Each factory planning project starts with the definition of objectives in the first phase. The objectives in factory planning are deduced from the corporate objectives and are specified according to the requirements of the factory planning project. Already in this phase it is necessary to define the main goals of sustainability. The project team has to gather all required information during the enterprise analysis and adapt the information for the following phases. The goal is a definition of all tasks in the project of a sustainable factory planning. The general planning can be seen as the core task of the factory planning process, because the whole factory is designed. [20] Next to the definition of objectives in this phase the basement of sustainable production is defined. Starting with the structure planning and dimensioning, an ideal layout is prepared. During the structure planning, decisions about thermal isolation or the technical buildings system are made. Those decisions have a great impact on the degree of efficiency with focus on sustainability. Based on this ideal layout, different layout variants are generated which consider restriction. These variants are evaluated according to the defined objectives. Actually, the evaluation is based on the design of the material flow or the efficient use of areas. Social or environmental optimization is actually not implemented in the evaluation process. The best variant is the input for the next phase, the detailed planning. Within the detailed planning the selected variant is put on a level of maturity for the implementation. The result is a detailed description and the visualization of all factory elements. The following phase is the implementation, where the results in the first phase are put into action. The

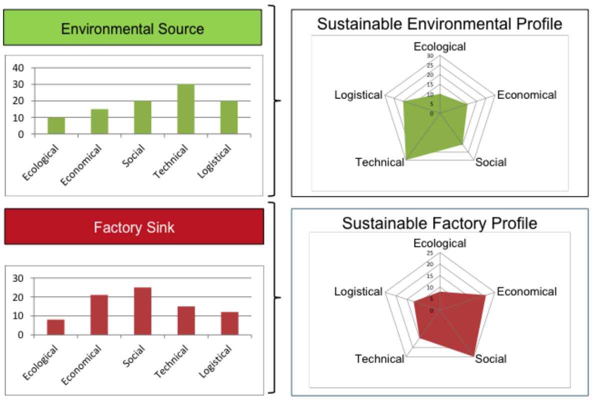


Figure 6: Sustainable Factory and Environmental Profile

implementation controlling contains the monitoring, coordination and documentation of the realization process. The factory planning project ends with the support of the production ramp up. [21], [22]

By recognizing all sustainable factors in each of those planning phases it is possible to realize and operate factories that are an integrated part in their environment. A main problem of this extended planning process is the rise of influences and restrictions to recognize within the described planning process. Sustainable planning is only useful if the basic objectives of the factory design are not compromised. Because of this, it is necessary to provide a concept, which is able to minimize all sustainable influences and factors to a useful and applicable complexity.

## 4 CONCEPT OF A SUSTAINABLE FACTORY PROFILE

With the main goal, to reduce the complexity of a sustainable planning process, the institute for advanced industrial management developed a concept of the sustainable factory profile. This profile supports the planning team by reducing the rising complexity caused by the integration of a holistic view of sustainable factory and a structured implementation into the planning process. The first step of this concept is the classifications of all recommend factors. Therefore, technological and logistic area extend the classic area of sustainability to the following. [23]

- Ecological area: Describes the increase and conservation of natural resources through the minimization of operational resource consumption
- Economical area: The sustaining and the increase of physical capital
- Social area: This area contains the maintenance of the internal human capital which consists of the know-how and the motivation of employees
- Technical area: This area describes the efficient planning and usage of technical equipment
- Logistical area: The logistic area describes the recognition of the whole supply chain with focus on sustainability

From each of the featured areas the factory takes resources as input for the production process (figure 1). The factory acts as a sink. In this context a sink is defined as a consumer of resources. On basis of this assumption it is possible to

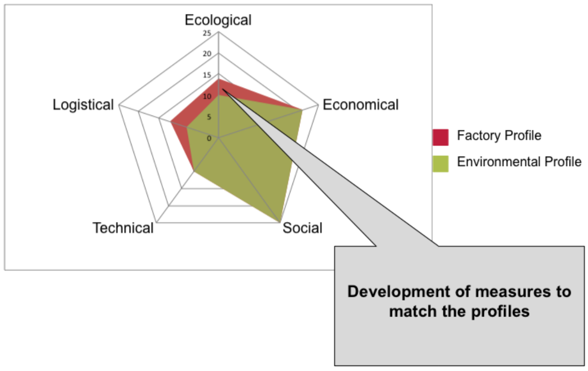


Figure 7: Sustainable Factory Profile

describe the whole factory as a combination of sinks. In the following some examples for sinks in the defined sustainably areas are shown:

- Ecological sink: The usage of fresh water
- Economical sink: The usage of capital for investments in strategic sustainable projects
- Social sink: The responsible use of employees
- Technical sink: The usage of energy to use highly efficient production or manufacturing plants
- Logistic sink: The logistic sink describes the recognition of external and internal supply of the factory. It includes the conveyance used and frequency of the supply. It defines the usage of transportation equipment like trucks or trains.

Through the structured recording of all sinks it is possible to develop a specific sustainable factory profile (figure 6). This assumes the normalization of all types of evaluation factors.

In the next step the environmental sources must be identified. Those resources are defined as source for the efficient usage in the factory. The procedure corresponds to the creation of the sustainable factory profile. The result is a sustainable environmental profile. In the following are some examples for environmental sources:

- Ecological source: If the production site has the potential of a fresh water supply by a river or similar
- Economical source: The Source of capital investment for the sustainable use in the factory
- Social source: A broad field of know how supply in the surrounding to reduce the approach road for the employees
- Technical source: A regional offer of equipment and utility supply
- Logistic source: The offer of regional suppliers to reduce the frequency of supply and the transportation way

By comparing the profiles in the next step the differences between sink and sources can be identified. The marked red area in figure 7 describes the difference/deviation. This delta defines the focus of future sustainable planning activities. In this example the logistic as well as the ecological areas contain disparities which have to be balanced. This area describes the focus which the planning team has to recognize in detail. In the next step it is necessary to develop measures and solutions to match the profiles and to find a fair balance between sink and source profile. In the following two examples are described for sustainable solutions for the logistic and ecological area.

*Ecological area*: If the surrounding of the factories is not able to provide the production process with renewable forms of energy it could be necessary to transform for example low temperature heat offered by surrounding factories or the urban environment into an efficient form of energy. In this case the so called heat and power installations (CHP) are one example to transform emissions in form of heat from other sources to a useful and high efficient source of electric energy for the factory. [3]

*Logistic area:* If the external supply of the factory is not realized by local or regional suppliers it must be a strategic goal to intense the supplier development with focus on sustainability. A regional or local supply of the factory decreases the $CO_2$ emissions caused by traffic.

Those examples show that the focus on those measures and solutions with the highest potential leads to new creative solutions in the field of sustainability. Due to the reducing of factors and influences, recognized during the planning and operation of a factory, the complexity can be reduced and the planning team is able to realize intelligent and creative solutions to raise the sustainability of the factory.

## 5 FURTHER RESEARCH

The concept shows an approach and defined structure to reduce the complexity of planning and operation of a factory with focus on sustainability. In further steps the evaluation and benchmark of the sustainable factory profile must be extended. Especially a basement of energetic profiles and date will be useful to ensure an objective result. Also a catalog of modules, solutions and measures to balance the profiles will rise the practical applicability for German and international producing enterprises.

## 6 CONCLUSION

Rising energy costs, new governmental restrictions like $CO_2$-certificates and growing environmental consciousness of consumers are new challenges for manufacturing companies. Thus, sustainability in planning and operating factories is getting more and more important to face the requirements in global competition. To make use of the whole potential of energy saving and sustainable design, it is unavoidable to extend the system boundaries through the entire value chain. The reduction of the complexity goes along with this extension. The institute for advanced industrial management developed a concept that supports the planning team to identify the main fields of sustainable planning which have to be focused. Thereby, the advantages of a sustainable planning and energy saving clearly outweigh the disadvantages of the raising planning complexity.

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